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(FOUO 2/79)

EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

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CONTENTS PAGE

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CHANGES IN THE PHYSIOLOGICAL PROCESSES OF HYDROBIONTS WHEN EXPOSED TO A CONSTANT MAGNETIC FIELD

Kiev GIDROBIOLOGICHESKIY ZHURNAL in Russian No 5, 1978 pp 56-62

[Article by A.I. Taneyeva, Institute for the Biology of the Southern Seas of the Ukrainian SSR Academy of Sciences, Sevastopol]

[Text] As a result of current wide-spread utilization of magnetic fields in many sectors of industry, science and technology, the need to study their effects on biological objects has grown. Investigators, in particular, are interested in the influence of orientation effects (9,20) of homogeneous and heterogeneous artificial magnetic fields on various aspects of metabolism, growth, development, and activity of plants and animals (9,16,20,21 and others).

We conducted experiments to elucidate the influence of heterogeneous and homogeneous magnetic fields of differing intensities and polarities on eggs (eggs were collected in the Sakskiy lake (Crimea) in 1970-71) and larvae of the brine shrimp Artemia Salina M. Edw. The artemia was selected as an experimental model because of its ability to respond to external environmental factors and the ease in which it can be obtained for laboratory use. In addition to these factors, artemia larvae have important significance from the stand-point of their mass cultivation as valuable nutrient matter for fish.

For the heterogeneous MF [magnetic field], an electromagnet was used with polar dimensions of 65 x 30 mm positioned opposite each other; the distance between poles was 30 mm. For the homogeneous MF, a horseshoe-shaped constant magnet was used with polar dimensions of 410 x 30 mm, positioned parallel to each other; the distance between poles was 39 mm. The intensity of the magnetic field on the eggs was 200 (heterogeneous MF) and 1800 (homogeneous MF) e [ergs]. After prolonged uninterrupted output by the electromagnet, temperature changes (accuracy ± 0.5° Centigrade) on the surface of the experimental area were not observed, eliminating the influence of this factor on the results. The intensity of the MF was measured by a teslameter F-43554/4.

Changes in the number of hatched larvae (percent), their rate of growth, and respiratory rate served as indices for the biological effect of the MF. Eggs of approximately similar diameter (0.20 mm) with intact shells were carefully selected for the experiment. The dry eggs were placed in weighing bottles (20 ml volume) which were filled with water of a given salinity. Four analyses were conducted in each experiment (100 eggs per analysis). For one analysis, the eggs were placed on the south pole of the magnet, for another--on the north ple. Two control analyses were conduced at the natural magnetic pole of the Earth. The terminal pole of the magnet was oriented towards the direction of the Earth's poles. Larval hatching occurred spontaneously in a magnetic field of 25-26°. The control eggs were found in analagous conditions. Counting of nauplius larvae was carried out at 36-40 hours when the maximum number of larvae were already hatched.

The solutions for all the experiments were prepared from filtered north sea water with additives of sodium chloride at the rate of 20 g/l. Food for the brine shrimp consisted of yeast cells and chlorella.

The length of the brine shrimp from the anterior edge of the head to the end of the tail was determined each day at a designated time using binoculars from a MBS [biological stereomicroscope] and a metered scale-ruler. Average sizes were determined. The dry weights were determined after dessication in an oven at 105°. The cumulative dry weight of animals weighed simultaneously was not less than 2-3 mg. Weighing was conducted on microanalytical scales SMD-1000.

The secondary effect of the magnetic fields on respiration of developing brine shrimp was determined by the Warburg apparatus. About 150 newborn larvae of approximately similar size were placed in the respirometer; their dry weight equaled 0.0026-0.003 mg. Respiration was measured at 20°, speed of respiration was expressed in $\mu l\ O_2$/mg of dry weight after 1 hour. Manometer readings were taken after each hour. The duration of the experiments was 3-4 hours. Data were calculated according to the method of variational statistics.

The studies did not show essential differences in the quantity of larvae hatched in an heterogeneous magnetic field with an intensity of 200 e and in a control field. In an homogeneous magnetic field at the south (S) pole, the quantity of larvae was greater than in the control by 53 percent ($P < 0.05$)--table 1. Some increase was also observed in the north (N) pole, however the differences between the test and control were shown to be statistically insignificant ($P > 0.05$).

1. Таблица 1. Влияние неоднородного (200 э) и однородного (1800 э) ПМП на выклев личинок A. salina

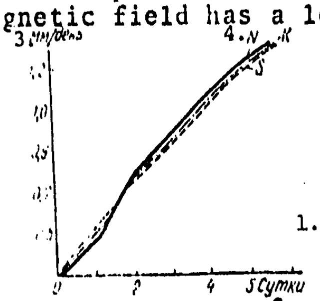
2. Напряженность, э	3. Вариант	4. Число выклюнувшихся науплиусов, экз.	5. %, к контролю	P
200	6. S	47,3±4,2	107	>0,05
	7. N	46,0±6,5	104	>0,05
	8. K	44,2±7,7	100	--
1800	S	61,6±4,2	153	<0,05
	N	47,6±6,7	118	>0,05
	K	40,2±6,1	100	--

9. Примечание. Приведены средние данные; в каждом опыте 100 шт. Здесь и далее: S — южный полюс магнита, N — северный, K — контроль, O — опыт.

1. Table 1. The influence of heterogeneous (200 e) and homogeneous (1800 e) PMF [poles of magnetic field] on hatching of A. salina larvae.
2. Intensity-e
3. Variant
4. Number of nauplius larvae hatched
5. Percent, for control
6. South
7. North
8. Control
9. Note. Mean data is presented; in each test there were 100 eggs. Sited here and elsewhere S--south pole of the magnet, N-north, K--control, O--test.

The study of the "magnetic sensitivity" of brine shrimp to the south and north pole of a magnet was interesting. The biological effect of the magnetic poles was determined according to changes in body length of the "magnet" larvae as compared to the controls.

Experiments demonstrated that an heterogeneous magnetic field does not influence the growth of larvae (see diagram), however, an homogeneous field increases growth rate (table 2). In addition, in larvae hatched near the south pole of the magnet, the growth rate was higher than in control larvae and in those developing near the north pole; in the latter, the average growth rate did not differ from the control. Thus, the nature and degree of polar influence on growth rate of larvae exposed to conditions of varying "magnetic sensitivity", depends on the pole of the magnetic field. We ascertained that the magnetic field has a long-lasting residual influence.



1. Скорость линейного роста личинок A. salina первых дней жизни при воздействии на них неоднородного магнитного поля (200 э).

1. Rate of body length growth of newborn A. salina larvae after exposure to an heterogeneous magnetic field (200e).
2. Day
3. mm per day
4. N--north, K--control, S--south

We followed the effect of the poles on respiratory rate of larvae hatched in a magnetic field. A marked difference between the test and control larvae following exposure to an heterogeneous magnetic field with an intensity of 200 e was not demonstrated (table 3). Analysis of the data showed that in newborn brine shrimp, a decrease in respiratory rate occurred after a 24 hour exposure to an homogeneous magnetic field; after 36 hours, the effect of the MF was noticeably weakened. From this fact, a definite relationship between respiratory rate of hatched larvae and magnetic field exposure was ascertained. Suppressed respiratory rate was less marked in larvae, developing near the north pole of the magnet. Thus, newborn brine shrimp in which oxygen intake was reduced following a 24 hour exposure to a MF with an intensity of 1800 e, demonstrated greater resistance to a MF than adult specimens (15).

Analysis of experimental data on the influence of an homogeneous MF on growth and respiration of brine shrimp reveals that growth increases in a magnetic field (south pòle) when oxygen consumption is reduced. Growth rate is dependent on the nature of gas exchange which results from changes in the processes of oxidation and phosphorylation, and a general decrease in anaerobic metabolism caused by the MF effect.

We assume that the increased growth rate of larvae, observed on the second day of exposure to an homogeneous MF, occurs not as a result of accelerated activity of the metabolic processes which are the bases for growth, but rather, as a result of tissue hydration. In this regard, experiments were conducted to determine the dry weight of two-day old larvae exposed to an homogeneous magnetic field.

1. Таблица 2. Влияние однородного магнитного поля на длину тела двухсуточных личинок A. salina

2. Вариант	n	3. Средняя длина тела, мм	4. % к контролю	P: 5. S и K	P: 6. N и K	P: 7. S и N
8. S	90	1,023±0,027	112	<0,05		<0,05
9. N	88	0,918±0,022	104		>0,05	
10. K	85	0,911±0,021	100	...	—	—

1. Table 2. Effect of an homogeneous magnetic field on the body length of two-day old A. salina larvae.
2. Variant
3. Average body length
4. Percent for control
5. South and control
6. North and control
7. South and north
8. South
9. North
10. Control

1. Таблица 3. Потребление кислорода личинками A. salina после действия на них магнитных полей

3. Варианты	2. Экспозиция в МП, ч: 1 — 4. мкл/ч на одно животное	5. % к контролю	P	24 — 4. мкл/ч на одно животное	5. % к контролю	P	[illegible] — 4. мкл/ч на одно животное	5. % к контролю	P
6. Неоднородное МП									
7. S	0,31±0,029	106	>0,05	0,20±0,076	90	>0,05	0,41±0,031	95	>0,05
8. N	0,30±0,029	103	>0,05	0,23±0,081	104	>0,05	0,42±0,022	97	>0,05
9. K	0,29±0,095	100	—	0,22±0,070	100	—	0,43±0,021	100	...
10. Однородное МП									
S	0,34±0,033	97	>0,05	0,15±0,027	44	<0,05	0,27±0,095	84	>0,05
N	0,37±0,042	105	>0,05	0,25±0,032	73	<0,05	0,29±0,024	90	>0,05
K	0,35±0,049	100	—	0,34±0,036	100	—	0,32±0,029	100	—

1. Table 3. Oxygen consumption by A. salina larvae after exposure to magnetic fields
2. Exposure to MF, hours
3. Variant
4. µl per hour in one animal
5. Percent for control
6. Heterogeneous MF
7. South
8. North
9. Control
10. Homogeneous MF

Dry weight of two-day old larvae growing in a magnetic field, calculated on the basis of length, was less than that of larvae unexposed to MF (table 4). Thus, one can assume that, given uniform body length in brine shrimp exposed to PMF, dry weight was decreased as result of greater water retention.

1. Таблица 4. Влияние однородного магнитного поля на содержание сухого вещества у двухдневных личинок A. salina

2. Вариант	3. Прирост, мм	4. Сухой вес одного животного, мг	5. Сухое в-во на 1 мм прироста	
			6. мг	7. % к контролю
8. S	0,393	0,0074	0,0188	77
9. N	0,330	0,0072	0,0218	89
10 K	0,291	0,0071	0,0244	100

11 Примечание. Приведены средние данные.

1. Table 4. The effect of an homogeneous magnetic field on the dry weight of two-day old A. salina larvae.
2. Variant
3. Growth, mm
4. Dry weight of one animal,mg
5. Dry weight per 1 mm of growth
6. mg
7. Percent for control
8. South
9. North
10. Control
11. Note. Mean data are presented.

Data in the literature on the effect of MF on tissue hydration are quite contradictory. A weak magnetic field decreases tissue hydration (5,18). A MF with an intensity of 1000 e stimulates development of eggs and increases the water retention capacity of their shells (10,11). It has been established (14) that increasing the exposure of artemia eggs to a MF with an intensity of 2000 e from 24 to 92 hours leads to changes which stimulate hatching of larvae.

Our studies also indicated that an homogeneous MF with an intensity of 1800 e has a positive influence on the metabolic activity of the eggs, enabling them to absorb greater amounts of water. Consequently, accelerated growth of recently hatched larvae occurs; the length of the brine shrimp on the second day of the experiment surpassed the length of the control specimens.

We surmise that stimulation for hatching of larvae is based on changes in water properties or increased permeability of membranes induced by exposure to an homogeneous MF. Thus, exposure activates metabolic processes in the embryo and effects subsequent growth of the brine shrimp after hatching.

The probable basis of MF influence on larvae is activation of the metabolic processes (8) which encourage accumulation of osmotically active substances in the egg. One of these substances is free glycerin, a break-down product of carbohydrates in the form of trehalose, the fundamental energy source for embryonic development (5). Trehalose increases internal osmotic pressure, causing the eggs to absorb water (24). A.S. Filippov and co-authors have demonstrated changing carbohydrate content in plants subjected to a MF (19).

A change in the configuration of protein macromolecules (4,11) which determine the processes of water absorption by the eggs, has not been ruled out as the basic mechanism of MF influence on water metabolism.

One can assume that the hydration of the developing brine shrimp body, exhibited on the second day of the experiment in the form of increased body length, is based on changes in water-mineral metabolism of the organism with a shift on the side of water and sodium retention. Changes in sodium concentration are caused by the effect of the homogeneous PMF on ion-protein binding processes (1,2,7). Sodium ions participate in the process of protein tissue hydration (6). It has been demonstrated previously (3) in studies on body length of experimental and control brine shrimp that prolonged exposure to a MF (2-7 days) causes reversal of larval growth. The processes which stimulate brine shrimp growth are replaced by those which inhibit it. Our data on brine shrimp growth concurs with data presented in the literature (12,18,22).

In our studies, we observed (in the first two days) electrolyte changes resulting from homogeneous PMF exposure which have the characteristics of a nonspecific compensatory reaction, detrimental to growth. The nonspecific character of the animals' reaction to an MF was exhibited in responses of the central nervous system, water metabolism disturbances, and changes in tissue hydration capacity (20,21). It has been reported previously (13) that a PMF with an intensity of 1-8,000 e causes changes in the hydration capacity of mussel tissue.

It is interesting to examine the degree of tissue hydration in a "magnetically sensitized" living organism. The sea acorn, Balanus eburneus, was used as the model for these studies. It is known that the quantity of water in the body of the balanus is altered when the animal is placed in solutions of varying salinity (17). A state of osmotic anabiosis develops, accompanied by decreased metabolic activity, suspension of motor activity, loss of light reflex and other sensory responses. Water content in the body of a brine shrimp placed in water with low salinity is increased and vice versa. When the brine shrimp are transferred to water with a salinity content common to their native habitat (17°/) they return quickly to a normal state and motor activity rêsumes.

We put brine shrimp in tanks filled with water of varying salinity and placed the tanks in the inter-polar space of a constant magnetic field with an intensity of 1050 e for 30 minutes to one hour. For these experiments, we used a constant homogeneous electromagnet with polar dimensions of 65 x 30 mm, situated opposite each other. The control sample was placed in the same water-filled container but not subjected to the MF. For optimum observation of the condition of the crayfish, their shells were removed before the experiment. For two hours prior to the beginning of the experiment, the balanus were placed in water with a 5 and 55°/∘∘ salinity content. During this time, motor activity of the animal ceased completely, reaction to spinal stimulation disappeared, and the brine shrimp became osmotically anabiotic. Following exposure to PMF, the brine shrimp remained in water with the same saline content for another hour, at which time they were transferred to common sea water (17°/∘∘). Further observations were conducted until the onset of death. Death was defined as cessation of motion in response to spinal stimulation. In each series of experiments, we determined the degree of brine shrimp hydration and dehydration by weighing them before and after residence in water of 5 and 55°/∘∘ salinity for a period of 30 minutes, one, and two hours. In all, nine sets of tests were conducted, each of which included six parallel experiments. Two groups (test and control) of experiments were conducted in common sea water (17°/∘∘), two--in water with lower salinity (5°/∘∘) and two--in higher (55°/∘∘).

The experiments demonstrated (table 5) that in water with 5°/∘∘ salinity, body weight of the balanus was increased by 34%, but in a concentrated solution (55°/∘∘), it decreased by 25%. Changes in the water content of the brine shrimp body during hydration and dehydration were in the range of 50% of normal, normal, and higher. The degree of hydration of a brine shrimp body placed in water with weak salinity and exposed to PMF with an intensity of 1050 e reached 146%. This was 12% greater than in the control ($P < 0.05$).

Thus, increase in water content of the crayfish body in test conditions alters the organism's "magnetic sensitivity". These data confirm that the reactions of biological objects to a MF are a combination of many harmful processes.

1. Таблица 5. Степень оводнения тела баланусов в воде пониженной и повышенной солености под действием ПМП (1050 э)

2. Соленость, ‰	3. Изменение веса (%) через							
	4. 30 мин		5. 60 мин		6. 120 мин		P	
	7. К	8. О	К	О	К	О	К	О
17	100	100	100	100	100	100	–	–
5	107	113	120	129	134	146	<0,05	<0,05
55	73	76	74	79	75	82	<0,05	<0,05

1. Table 5. Degree of hydration of the balanus body when placed in water of lower and higher salinity after PMF (1050 e) exposure.
2. Salinity °/oo
3. Weight change (%) after
4. 30 minutes
5. 60 minutes
6. 120 minutes
7. K--control
8. O--test

Conclusions

1. An homogeneous MF with an intensity of 1800 e intensifies hatching of A. salina larvae and accelerates their growth rate.

2. An homogeneous MF suppresses oxygen consumption of developing crayfish; however, animals located near the north pole of the magnet exhibit this phenomena to a lesser extent.

3. Dry weight of larvae hatched in a MF, calculated on the basis of body length, was found to be less than the weight of unexposed larvae.

4. Given different MF intensities, the "magnetic sensitivity" of brine shrimp appears to be stronger in an homogeneous field in comparison to an heterogeneous one.

5. Increase in water content of the brine shrimp body alters its "magnetic sensitivity".

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THE EFFECT OF ELECTRIC FIELDS ON DROSOPHILA BEHAVIOR

Moscow IZVESTIYA AKADEMII NAUK SSSR, SERIYA BIOLOGICHESKAYA in Russian No 5, Sep-Oct 1978 pp 723-731

[Article by V. B. Chernyshev and V. M. Afonina, Moscow State University imeni M. V. Lomonosov: "The Effect of Electric Fields on Drosophila Behavior (Drosophila Melanogaster Meig)", received 26 Sep 75]

[Text] When exposed to a constant or alternating electric field, drosophilas placed between the plates of a condenser cease to move. The percentage of the drosophilas responding to the field is directly proportional to the field intensity and inversely porportional to air humidity and, apparently, to the infrasonic background. The effect is maximal at the frequency of 10 hertz; it does not depend on the polarity of the condenser plates, their contact with the drosophilas, ionization and electric conductivity of the air, atmospheric discharges, atmospheric pressure, and the disturbances of the geomagnetic field. There are no responses in winter. It is assumed that drosophilas are affected by mechanical forces arising during the interaction of the body charge with the external field.

The electric field is an ordinary natural factor. The intensity of the electric field of the atmosphere in clear weather near the surface of the earth is approximately 150 v/m, however, in thunderstorm weather it reaches tens of thousands of volts per 1 m.

The effect of electric fields on the organism has not been sufficiently studied. However, a number of facts are available now which indicate that the electric field can exert appreciable influence on the behavior of land animals, particularly insects.

In fact, a considerable part of the drosophilas placed between the plates of of a condenser cease to more when a relatively small potential is delivered to these plates (Edwards, 1960). An analogous response was observed by us in the beetle Dermestes sibiricus Er; however, when the plates are connected to a current source, clothes moths sometimes display short excitation replaced subsequently by inhibition (Afonina et al, 1973). Let us stress that the level of the responses of these beetles and moths, for reasons unknown to us, were characterized by a high degree of instability, and it was not possible to reproduce the experiment every day. When small insects move over a nonuniformly charged surface, they perceive an increase in the charge as an obstacle (Maw, 1961).

The shielding from the surrounding fields also has an obvious effect on the behavior of insects. For example, Shoven (1971) writes, referring to unpublished data of Lepoint, that the shielding of juniper bushes with a grounded Faraday's cage resulted in a noticeable increase in the number of insects on these bushes. In our experiments, the shielding of the soil surface resulted in an increase in the number of small insects and mites in the shielded section, on the average, 1.5 times in comparison with the control (Tshernyshev et al, 1973).

Thus, it is possible to consider proven that insects respond to the electric fields around them. However, their field perception mechanism remains unknown.

We found the two following hypotheses to be the most convincing:

1) a weak electric current appears in the electric field and flows through the air and body of the organism; it is this current that causes a response (Germer, 1971);

2) the body of any land organism is, as a rule, charged to a certain degree; as a result of the interaction of these charges with the external field, there appear mechanical forces which are perceived in one way or another (Tshernyshev et al, 1973).

The above-mentioned facts, as well as other facts indicating the influence of electric fields on live objects can be interpreted in favor of any of these hypotheses. It is evident that the validity of one of these hypotheses can be proven by physical experiments.

If the first hypothesis is true, the reaction must increase with increase of the current flowing in the field, i.e., with increase of the ionization and electric conductivity of the air, better contact of the object with the current-conducting surface, and increase in the humidity of the air and the substratum on which the object is located.

However, if the second hypothesis is true, then the relationship must be completely opposite, because all of the above-mentioned conditions are favorable for the draining of the body charge, and, consequently, reduce the forces of the interaction between the charges.

This article describes the responses of drosophilas to electric fields of various parameters. We tried to understand the field perception mechanism, as well as the reasons for the variability of the responses.

Materials and Methods

We studied flies Drosophila melanogaster Meig (wild type) which are cultivated in the Department of Genetics of the Moscow State University.

We studied the effect of the electric field on the mobility of these flies. Plate batteries, an autotransformer, or an infralow-frequency oscillator GZ-16 served as the sources of the necessary potential.

Here, we shall dwell chiefly on the methods common for all experiments. Special methods are described together with the results of the appropriate experiments.

In order to observe the responses of the drosophilas to the electric field, we used chambers made of Petri dishes. A round copper plate connected with one of the terminals of the current source was placed within each dish. The insulation material was a circle of thick white paper approximately of the same diameter placed on the plate, and a ring of the same paper 3-5 mm high and 50-60 mm in diameter was placed on top of it. On top of the paper ring, another Petri dish was placed with a saturated NaCl solution and a wire circular electrode within it. Thus, a working space of the chamber was created whose bottom was the copper plate and paper and the ceiling was the second "plate" -- the glass plate with the solution of the electrolyte, and the side walls were formed by the circular strip of thick paper. The transparent upper "plate" made it possible to observe easily the behavior of the objects which were within the field.

As a rule, the experiment was conducted with six such chambers simultaneously. These chambers were placed in a special thermostatically controlled vessel enclosed in glass and illuminated from the top by an incandescent lamp. As a result, a constant temperature of 27° C was maintained in the chamber, the illumination was about 400 lx, and the air humidity was about 70 % due to the open upper plates with the saturated salt solution.

One hour before the experiment, ten flies subjected to ether anesthesia were placed in each chamber. By the beginning of the experiment, normal behavior of such flies was fully restored.

At the beginning of the experiment, the number of active flies in each chamber was counted ten times in the course of approximately 10 minutes, then the necessary electric potential was fed to the plates, and the mobility check was repeated in the same manner. In approximately 10 minutes, the current was turned off and the mobility of the flies was determined for the third time. As a result of this we had 60 mobility checks before, during, and after the exposure to the field, which made it easy to make statistical comparison by the Student criterion.

On the basis of the obtained data, the following indices were calculated: response level -- percentage of the drosophilas which ceased moving after the field was turned on (the ratio of the number of the drosophilas which stopped moving under the effect of the field to the number of the active drosophilas before the experiment); the percentage of the drosophilas which were active before the experiment, during the experiment, and after it.

A considerable part of the experiments were conducted at the base of the Main Geophysical Observatory (GGO) in Voyeykovo near Leningrad. The authors are very grateful to the staff of the Department of Atmospheric Electricity of the GGO for their technical help, the results of geophysical measurements which were made available to them, and consultations.

All the remaining experiments were conducted at the agrobiological station of the Moscow State University "Chashnikovo" near Moscow.

General Picture of the Responses to the Electric Field. When a field of sufficient intensity was turned on, a considerable part of the drosophilas or even all of them ceased to move. The response becomes noticeable 1-2 sec after the plates are connected with the source of current, but sometimes it continues to increase in the course of 1-2 minutes. Many flies move from the bottom of the chamber to its side wall, always assuming a vertical position with their heads up. At low field intensities of the order of several volt/cm, the mobility of the flies restores in the field several minutes after it is turned on, and at high intensities (hundreds of volts/cm),the response is maintained for hours without changes.

After the field is turned off, their mobility restores rapidly to the original level. The final mobility level is reached after several seconds, and sometimes after one minute. As a rule, the slower the response builds up in the field, the longer it takes for the original mobility level to restore. The response to the alternating field does not differ superficially at all from the response to the constant field. One of the examples of the response described above is shown in Figure 1.

Figure 1. The response of the drosophilas to the alternating electric field (220 v/cm, 50 Hz). Y-axis -- percentage of active drosophilas, X-axis -- time, min. The arrows show the moments when the field was turned on and turned off.

Key: 1. Min

Dependence of the Response on the Field Parameters. a) Intensity. The response level depends clearly on the field intensity, both of the constant field and alternating field. The response level increases particularly sharply with intensity in the interval from 0 to 50 v/cm, i.e., to the usual intensity level in a thunderstorm weather. However, even witn intensities of about 250 v/cm, the response continues to increase with increased potential. Figure 2 shows the results of one of such experiments. A completely analogous relationship was obtained in all other experiments, but the average response level differs for different days.

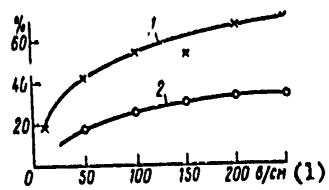

Figure 2. Dependence of the response level of the drosophilas on the intensity of the constant (2) and alternating (50 Hz) field (1).
Key: 1. v/cm

The minimal intensity at which it was still possible to notice a response of short duration was 2 v/cm. This intensity can occur in natural conditions when small clouds pass overhead.

b) Polarity of the Plates. The response does not depend at all on the sign of the charge of the upper and lower plates. The relations between the response levels in the case of the positive charge of the upper plate and positive charge of the lower plate in two experiments with a field intensity of 80 v/cm where 1,0 and 0,8, and in two other experiments at 240 v/cm -- 1,0 and 1,1. The response varied noticeably during the experiment, therefore, the differences of the responses with different polarities of the plates are clearly unreliable.

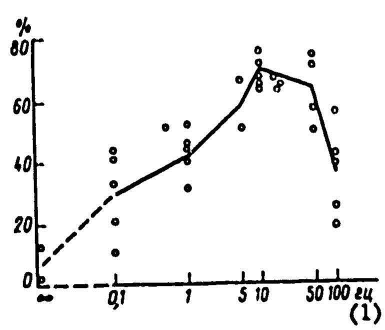

Figure 3. Dependence of the response level of the drosophilas on the field frequency.
Key: 1. Hz

c) Frequency. The dependence of the response on the field frequency is quite obvious. The highest and the most stable response was observed when sinusoidally changing potential with a frequency of 10-50 Hz was fed to the plates (Figure 3). The level of the response falls both when the field frequency is increased and when it is lowered ($P > 0.95$). The response in the constant field is lower than in the alternating field (within the range of the sinusoidally changing potential from 0.1 to 100 Hz which we studied).

Dependence of the Response on the Electric Conductivity and Humidity of the Air and the Substratum on the Bottom of the Chamber. a) Ionization and Electric Conductivity of the Air. The results of 65 daily observations conducted under strictly standard conditions and at standard time (about 17 hours and 30 minutes by local standard time) were compared with the indices of natural concentration of ions and electric conductivity of the air. Measurements of the concentration of positive and negative ions were conducted several times a day, including directly before the experiment in the room where the response of the drosophilas to the field was observed. Measurements were done with an ion counter of Tverskoy's system.

Positive and negative average hourly electric conductivity of the air was measured near our laboratory by the members of the department of atmospheric electricity of the GGO by means of the Allik unit.

In spite of the apparent stability of the experimental conditions, the response level of the drosophilas was different on different days, varying from 13 to 93 %. However, we were unable to detect any correlation between the response level and the results of the measurement of the ionization and electric conductivity of the air.

In the subsequent series of our experiments, we artificially changed the ionization and electric conductivity of the air. Lower levels of ionization and electric conductivity were created by screening the chambers with smoke. Increase in these indices by several orders was achieved by placing radioactive collectors directly inside three experimental chambers. Experimental sources of alpha-rays with a plutonium isotope (Pu_{239}) were used. The value of the ionization current reached, on the average, about $0.6-6.0 \cdot 10^{-10}$ a. The size of the active part of the collector was 32 mm, and the activity in the source was 0.019 m-curie. For the control, metal rubles which are close in size and shape to the collectors were placed in three other chambers.

In two out of five experiments, the screening of the chambers with smoke resulted in a slight decrease in the response, and in three other experiments in a slight increase. Two experiments with the radioactive isotope yielded a response ratio in the experiment to the control without the isotope of 1,1 and 0,9.

Thus, the level of the ionization and electric conductivity of the air both within the natural range, and beyond its boundary did not exert any substantial influence on the response of the drosophilas to the field.

b) Contact of the Drosophilas' with the Current-Conducting Surface. In one series of experiments, the paper lining was removed from the current-carrying lower plate. As a result of this, the drosophilas were crawling directly on the polished copper plate. The relations of the response levels with and without contact in five experiments were as follows: 1,1, 1,0, 0,9, 1,2, and 1,3. The differences between the experiments and the control are obviously uncertain.

Thus, according to our data, direct contact between the drosophila and the current-conducting surface hardly changes their response to the field. Let us note that in Edwards' experiments (1960) drosophilas responded to the field only during contact with a current-carrying surface. It is true, however, that this contact is very relative due to the well-known high electric resistance of the body integuments of insects.

c) The Effect of Air Humidity on the Response Level. Different levels of air humidity in the chambers was created by means of saturated salt solutions (NaCl about 77 %, $Ca(NO_3)_2$ about 56 %, $MgCl_2$ about 34 %) as well as by means of braided pieces of cotton soaked in water (about 100 %) and calcined granules of calcium silicate (about 0 %). The salt solutions and cotton braids were placed in circular plastilin troughs surrounding the experimental chambers. These troughs were lower than the side paper walls of the chambers by fractions of 1 mm, due to which air of a definite degree of humidity entered the chamber.

Each experiment was conducted with three degrees of humidity. All experiments necessarily included a variant with 56 % humidity. The minimum number of experiments were done at a humidity of 0 % (three experiments, 30 observations), and the maximum number of experiments were done at 56 % humidity (13 experiments, 130 observations).

If we take the response level at 56% humidity to be equal to unity, then we small obtain the following dependence of the response level on the humidity: 0% hunidity -- 0.4; 34% -- 1.1; 56% -- 1; 0.77% -- 0.8 and 100% -- 0.3.

All differences are highly certain ($P > 0.999$) with the exception of responses at 34 and 56 % humidity. Thus, when humidity increased in the interval from 34 to 100%, the response falls off clearly.

If drosophilas stay for several hours in chambers with different levels of humidity, the response in the chambers with low humidity (34 and 56 %) declines noticeably and, finally, the response levels at a various degrees of humidity come closer together. Evidently, this decline in the response level is connected with the "drying" of the drosophilas, which becomes noticeable in the chamber with zero humidity even at the beginning of the experiment.

Biological Variability of Responses. The responses of the drosophilas to the field are practically independent of their age. Responses of males are somewhat higher than those of females. There is a very weak positive correlation between the preliminary level of mobility of drosophilas before the experiment and the level of the response, however, it is not certain.

As a rule, responses are somewhat higher in the second half of the day, during the time of the maximum mobility of the drosophilas.

There is a marked seasonal periodicity of the responce in spite of the fact that the culture is kept under constant temperature and stable conditions all year round. The optimal time for the observation of responses is May-June, although very high responses can be observed during other months. Unfortunately, standard experiments were not conducted every month. Nevertheless, there were definite regularities: in February, none of the ten experiments yielded noticeable responses, one experiment conducted in March gave a weak response -- 25%, three experiments conducted in April yielded an average of 63%, one experiment in May -- 82%, 19 experiments in June and 24 experiments in July -- an average of 71 and 56%, respectively. One experiment in August yeilded an unexpected high response -- 79 percent, three experiments in September -- an average of 48%, one experiment in October -- 2% (although nonstandard experiments conducted in October show that a rather high level of response is observed sometimes during this month). From November until spring, we were unable to observe any responses of drosophilas to the field.

Recurrence of the Effect. We have already mentioned that the minimum level of the response observed by us in the summer was 13%, and the maximum level was 93%. Both of these levels were observed on the days which were close to one another in drosophilas of almost identical age from a standard culture,at the same time of day, and the same illumination, temperature, and air humidity.

It is natural to assume that this variability of responses can be caused only by some external causes, i.e., some factors which are usually not controlled and which penetrate through the walls of the laboratory.

We have already conducted experiments which showed that ionization and electric conductivity of the air cannot be these factors. In search of these factors, we analyzed correlations between the levels of various natural factors and response level in 65 daily standard experiments. Moreover, a number of additional experiments were conducted, which revealed the influence of certain artificially created factors on the response level.

a) Electromagnetic Oscillations of Atmospheric Origin (atmospherics). The average hourly number of the discharges of atmospherics at a frequency of 7.2 kHz was determined by the members of the department of atmospheric electricity of the GGO with the aid of a storm recording device. We did not detect any correlation between these indices and the response level of the drosophilas.

We also tried to determine the effect of atmospherics by artificially changing their level. The lowering of the level of the atmospherics was accomplished by shielding the chambers with an iron net (wire diameter 0.5 mm, size of mesh 2 mm). Higher levels of atmospherics were created by the following four methods:

-- Potential from a G5-7A oscillator was fed to the plates of the chambers for an hour before the experiment.

-- The same potential from the same oscillator was fed to the plates both before the experiment and during it.

-- A magnetic tape recording of natural atmospherics was fed to the plates before and during the experiment.

-- Artificial discharges were created near the chamber during the experiment.

No certain changes in the responses were detected in any of these variants of the experiment.

b) Gradient of the Atmosphere Potential. Measurements of the gradient of the atmosphere potential are conducted constantly by the members of the department of atmospheric electricity of the GGO. This factor is not one of the factors penetrating into closed laboratory premises. Nevertheless, in our search for a mutually correlated complex of factors, we tried to find correlation between the potential gradient and the response level, but did not succeed.

c) Perturbed Variations of the Geomagnetic Field. Continuous observations of the state of the geomagnetic field were conducted near our laboratory by the members of the IZMIR [Institute of Terrestrial Magnetism, the Ionosphere, and Radio Wave Propagation] of the USSR Academy of Sciences. The three-hour indices of geomagnetic perturbance K and 24-hour sums of these indices ΣK which were made available to us by the members of the institute did not show any correlation with the response level. However, after a very heavy magnetic storm of 6 July 1974, we observed a total depression of both mobility, and the response of the drosophilas to the field.

d) Atmospheric Pressure. We did not detect any correlation between the response levels and the atmospheric pressure (three-hour indices according to the data of the meteorological station at the GGO "Voyeykovo" base).

e) Infrasonic Background. Infrasound is an ordinary factor which, however, as a rule, is not taken into consideration by researchers. Sources of infrasound can be wind, various vehicles, industrial installations, and elevators in buildings. Moreover, powerful infrasounds which spread very far occur in polar auroras occurring during heavy geomagnetic storms, earthquakes, eruptions of volcanoes, as well as during the movement of large atmospheric fronts (Vladimirskiy, 1974). Very little is known about the effect of infrasound on live organisms.

In our experiments in a cylindrical chamber (height 50 mm, diameter 105 mm), we created alternating compression and rarefaction of the air corresponding to the passing of an infrasonic wave. The bottom of the cylinder was covered with a rubber film in the center of which a tin plate 20 mm in diameter was glued. A small electromagnet was secured below the cylinder. When electric current passed through the electromagnet, it pulled the plate and the film 1.5-2 mm downward. Thus, the amplitude of the occurring infrasound was of the order of 10 dyn/cm^2. The source of sinusoidal low-frequency current fed to the electromagnet was a GZ-16 oscillator. The main experiments were conducted with a current of 8 Hz. Consequently, the infrasonic oscillations occurring in response to each half-cycle of current had a frequency of 16 Hz and verged on the sound audible to man. At the top, the cylinder was hermetically sealed with a glass lid.

An ordinary chamber used for observing the responses of drosophilas to the field (220 v/cm, 50 Hz) was placed within the cylinder. Other chambers outside the cylinder served as the control. In order to avoid vibration as far as possible, the chamber within the cylinder was suspended on rubber strips, and the chambers outside the cylinder were placed on a thick porolon lining. The intensity of the current passing through the magnet was regulated in such a way that the plate would be attracted to the magnet but would not hit it.

The experiments started with observation on the responses of the drosophilas to the electric field before the infrasound was switched on. Having convinced ourselves that the response levels in the experimental and the control chambers were close to one another, we switched on the infrasound. The drosophilas were under its influence for 1.5-2 hours. After this, we observed again the responses of the drosophilas to the field of the same parameters with the infrasound switched on.

In 1.5-2 hours, the response level changed both in the experiment, and in the control. However, the response remained at the same level only in two out of the sixteen experiments with infrasound. In all other instances, the response dropped considerably and reached, on the average, about 0.6 of the former level. The decline of the response under the effect of infrasound was highly certain ($P > 0.999$).

In eight control measurements of responses, their level could change in any direction. However, on the average, the response remained at the former level (1.0).

Special experiments with an electromagnet showed that the variable magnetic field penetrating into the chamber together with the infrasound could not cause changes in the response level.

Thus, the preliminary experiments conducted by us indicate that the infrasonic background could be the probable cause of the variability of the response level of drosophilas to the electric field. In any case, this was the only factor under whose effect we observed changes in the responses while all other conditions were standard. Evidently, the more intensive the infrasound and the longer its effect, the higher is the threshold of the response of the drosophila to the field. Several additional experiments conducted by us showed that an infrasound with a frequency of 0.1 Hz, evidendly, also lowers the response level. However, low sound frequencies, evidently, on the contrary, increase the responses of drosophilas.

In this connection, it is interesting to note that almost all observations conducted in the city laboratory showed no responses of drosophilas to the electric field. All results cited here were obtained in experiments conducted in a rural area, where the vibrational background and the infrasonic background connected with it are considerably weaker than in the city. Also, it is not ruled out that the absence of responses which we observed after a heavy magnetic storm was connected with the effect of powerful infrasounds of natural origin on the drosophilas.

The results obtained by us show that natural electric fields must have a substantial effect on the behavior of drosophilas. Increase in the electric field intensity which, as a rule, is connected with the appearance of clouds and the approaching of foul weather, hinders the mobility of drosophilas and, evidently, their flight, as a result of which the drosophilas move to sheltered spots.

Our observations also make it possible to suggest some ideas about the field perception mechanism. The main facts obtained by us are as follows: 1) response increases with the field intensity; 2) response is similar in the alternating and constant fields; 3) the response level is lower in the constant field than in the alternating field, and the response is maximal at the frequency of 10 Hz; 4) the response does not depend on the polarity of the plates; 5) the response is practically independent of the level of the ionization and electric conductivity of the air; 6) the response does not depend on the contact of the drosophilas with the current-conducting plates; 7) the response increases as air humidity decreases in the interval of 100-34%.

The hypothesis proposed by us regarding the perception of the field as mechanical forces arising under the interaction of the body charge with the external field is in line with these facts. However, the absence of a connection between the response and the electric conductivity of the air is inconsistent with this conclusion, but, evidently, the drainage of the body charge is negligible even at a high level of electric conductivity of the air.

The hypothesis that the field is perceived as a current flowing through the air and the body of the organism is inconsistent with the facts that the response increases as the air humidity decreases and that the response is independent of the contact with the plates and the level of the electric conductivity of the air.

If our hypothesis is valid, the alternating field must cause a peculiar swinging of the object. We assume, that resonance phenomena are also possible here. If we assume that the body of a drosophila is fixed at one point, then the resonance frequency for such a "pendulum" must be about 10 Hz, which is well in agreement with the results of the experiments. Responding to an additional force, as well as to "swinging", the drosophila ceases to move, which can be easily observed by placing the drosophila in an air stream in which turbulent oscillation phenomena always occur near the walls.

However, we believe that it is premature to explain the response to the field by the perception of mechanical effects alone.

The studies conducted by us also make it possible to estimate the effects of various "penetrating" factors on the reproducibility of the experiment. Searching for such biologically active factors is one of the main problems arising in studying the effects of the weather and solar activity on organisms, as well as biological clocks.

Our data show that one of such factors could be infrasounds both of natural and artificial origin.

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THE EFFECT OF STRONG MAGNETIC FIELDS ON THE ACTIVE TRANSPORT IN THE CHOROID PLEXUS

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[Text] Until recently, it was doubted that magnetic fields could affect biological objects. In fact, since almost all molecules which enter into the composition of biological tissues and organs are diamagnetic, the magnetic field is capable of inducing in them a very small magnetic moment $\mu = \varkappa H$, where H is the magnetic field intensity, and $\varkappa$ is magnetic susceptibility. The energy acquired by such a moment in the magnetic field μH is vanishingly small in comparison with the energy of thermal motion kT (k -- Boltzmann's constant, T -- absolute temperature). Thus, for the magnetic field $H = 8 \cdot 10^5$ A/m(10^4 Oersted) the relation $\mu H/kT < 10^{-6}$. It is clear that any noticeable effect of the magnetic field on individual biological molecules is out of the question. However, there are exceptions to this general rule: liquid crystals (mesophases). They form oriented domains containing millions of individual molecules. It is well known that liquid crystals are oriented by magnetic fields, since the criterion $\mu H/kT$ for them becomes noticeably greater than one. This is the result of simultaneous orientation of millions of molecules forming the domains.

Typical representatives of smectic liquid crystals are lipoids from which all biological membranes are built. Therefore, the orientation effect of the magnetic field on the fragments of biomembranes is well established [1, 2]. One of the functional manifestations of magnetic orientation was studied by us in works [3, 4] in which we investigated the active transport of fluorescein by the membranes of the tubules of the kidneys of the frog.

This work gives the results of studies on the influence of the magnetic field on the active transport of fluorescein in the choroid plexus of a rabbit brain. This object has a substantial advantage over the kidney: its epithelial cells form folds which, on the average, are arranged in a particular manner in relation to the macroscopic plane of the organ. Therefore, it is possible to accomplish the orientation of the membranes of the plexus in relation to the magnetic field.

The technique of the removal of the choroid plexus and the method of measuring the concentration are described in work [5]. In order to study the effect of the magnetic field on the transport of fluorescein, the choroid plexus was straightened out between two nylon nets secured in special frames. The latter were placed in a constant-temperature vessel located between poles of an electromagnet or in the "warm" channel of a superconducting solenoid. By turning the frame around its axis, we could orient the membranes of the plexus in relation to the magnetic field in various manners. The second plexus of the same animal was used as a control and was incubated simultaneously with the first plexus outside of the magnetic field. In each experiment we used 4-5 pairs of choroid plexuses. The measurements of fluorescein were repeated 30-40 times in various sections of the same membrane. The incubation medium was Ringer-Henks solution of the following composition (in mM): NaCl 136.8; KCl 5.4.; $CaCl_2$ 1.25; $MgSO_4$ 0.4; $MgCl_2$ 0.5; Na_2HPO_4 0.34; KH_2PO_4 0.45; glucose 5.5; $NaHCO_3$ 4.1; the pH of the solution was maintained at a level of 7.4-7.5. In the instances when the content of ions of Ca^{2+}, Na^+, or K^+ changed in the incubation medium, the overall osmomolarity of the solutions was maintained at a constant level by adding choline chloride or by compensating with other cations. Oxygen was blown through the solution in the course of the entire incubation time. The transport rate of fluorescein was determined by measuring the concentration of the fluorescein passing inside the plexus in 15 minutes of incubation. The concentration of fluorescein in the medium in all experiments was 10^{-4}M. The fact that we were dealing with active transport of fluorescein and not with diffusion was proved by the fact that transport progressed against the concentration gradient. Within the plexus (in blood capillaries), fluorescein concentration at the end of incubation was 8-12 times higher than in the surrounding medium. For each pair of plexuses (taken from one rabbit), the average ratio of "experiment" (transport in the magnetic field)/"control" (transport outside of the field) was determined. Then, these relative values were averaged over the entire series of animals and a 95 % confidence interval was calculated. The experiments conducted by us showed, first of all, that influence of the magnetic field on the active transport of fluorescein depends critically on the orientation of the membrane. Only with the normal orientation of the plane of the plexus in relation to the vector of the magnetic field intensity, the latter has a strong effect on the transport. However, if the plane of the plexus is parallel to the field, the effect is insignificant. Intermediate results are obtained with other angles. Therefore, in all experiments described below, the plexus plane was arranged perpendicularly to the direction of the magnetic field. This means that the plicate membrane of the plexus was oriented chiefly along the lines of force. In these experiments, the magnetic field intensity was maintained constant and equal to $1.75 \cdot 10^6$ A/m ($22 \cdot 10^3$ Oe). The temperature of the medium was 36 degrees C, and the incubation period was 15 minutes.

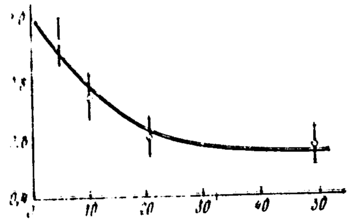

Figure 1. The effect of the magnetic field intensity on the transport of fluorescein in the choroid plexus. On the Y-axis -- the ratio of the fluorescein transport in the magnetic field to the transport outside the field. Incubation conditions: fluorescein concentration in the medium 10^{4-} M, concentration of calcium ions 0.12 mM, incubation period 15 min.

The following incubation conditions were changed: 1) concentration of sodium ions; 2) concentration of potassium ions; 3) concentration of calcium ions; 4) introduction of K-strophanthin into the incubation medium; preincubation of the choroid plexus in the course of 2.5-3 hours at 0 degree C.

The main results of the experiments are shown in Table 1.

Table 1
The Effect of the Magnetic Field on the Active Transport of Fluorescein in the Choroid Plexus

Incubation Conditions	Experiment / Control	Number of Animals
Normal Ringer-Henks solution	1.86±0.07	4
Solution with a low concentration of Ca^{2+} (0.1 of normal)	0.49±0.08	5
Normal solution with addition of K-strophanthin (5·10 M)	1.88±0.21	4
Solution with a low concentration of Ca^{2+} with addition of K-strophanthin	1.90±0.17	5
Medium without sodium (sodium replaced with choline chloride)	0.93±0.06	4
Medium without potassium (potassium replaced with sodium)	1.05±0.05	4
Normal solution, membrame pre-incubated at 0°C	1.00±0.10	4

The main result of our studies are: almost a two-fold increase in the fluorescein transport under the effect of the magnetic field in a normal incubation medium and a completely opposite effect (inhibition of transport) in the medium with a low concentration of calcium ions. Addition to the normal incubation medium of K-strophanthin, which is an inhibitor of K^+, Na^+-

dependent ATPase [adenosinetriphosphatase], does not change the relative effect of the magnetic field on the transport. However, if K-strophanthin is added to a medium with a low calcium concentration, then the opposite effect is observed: the magnetic field begins to stimulate the transport of fluorescein in the plexus.

Figure 1 shows the dependence of the effect of the magnetic field on the transport upon the field intensity in the incubation medium with a low concentration of Ca^{2+} ions. We can see that saturation sets in at a field intensity of $\sim 2.5 \cdot 10^6$ A/m. The stimulation effect of the magnetic field on the transport in a normal incubation medium has an analogous form.

As has been mentioned above, lipoid molecules forming liquid-crystal domains can be a substantial real object of the influence of the magnetic field in a biological membrane. The structure of the membrane is determined by the influence of a number of factors on the lipoid domain: electrical field generated by the ionic pump depending on K^+, Na^+-dependent ATPase; thermal motion of lipoid molecules, the greater, the less the strength of linkage between them and the viscosity of the lipoid layer. In turn, the structure of the lipoid layer can determine the orientation of the transport channels in the membrane, as well as the activity of a number of enzymes built-in into the membrane, primarily ATPase.

In order to determine whether or not the effect of the magnetic field on the transport is connected with the changes in its potential, we studied the adsorption by the choroid plexus of a negatively charged fluorescent dye 1, 8 aniline-naphthalene-sulfonate (ANS) whose ability of being adsorbed on the membrane depends on its potential [6]. Measurements were conducted in the following manner: a) The plexus was kept for one minute in a normal medium containing 10^{-4} M ANS and then was washed for 30 minutes in a medium without ANS. Such experiments were conducted both in the magnetic field and outside the field. After this, the fluorescence of both membranes was measured and the "experiment"/"control" ratio was calculated, which was found to be equal to 1.04 ± 0.02. b) The plexus was incubated in a normal medium without ANS (one membrane in the magnetic field, and the other outside the field). Then they were submerged in an ANS solution for one minute, rinsed in a solution without ANS, and fluorescence was measured. In this case, the "experiment/control" ratio was 1.01 ± 0.01. Evidently, the magnetic field does not exert an appreciable effect on the transmembrane potential of the choroid plexus. A possible explanation of the effects observed by us is the influence of the changes in the orientation of the lipoid layers under the effect of the magnetic field on the channels for the transport of organic acids or on the activity of K^+, Na^+-dependent ATPase built-in into the membrane. Under the conditions when the work of this enzyme is suppressed considerably (for example, during incubation at a low temperature or when potassium ions are excluded from the incubation medium), the magnetic field does not exert influence on the process of the active transport into the plexus. Under these unfavorable conditions, as is shown by the results of our preceding work [5], the rate of the active transport decreases by approximately 50 % and, evidently, no structural changes caused in the membrane by the magnetic field are capable of exerting an appreciable effect on the transport process. K-strophanthin, which inhibits the work of ATPase, evidently, changes the structure of the enzyme-lipoid complex. The effect of the magnetic field in this case consists in compensation of these unfavorable structural changes. Calcium has a substantial effect on the structure of the phospholipoid layer due to the interaction with the phosphate groups. Its absence causes considerable changes in the structure of the domainsand the effect of the magnetic field changes its sign. Thus, we see that the problem of the effect of the magnetic field on the processes occurring in the membrane is quite complicated. In order to solve it, it is absolutely necessary to conduct structural studies on membranes in a magnetic field so as to have a clear idea about the nature of the orientation of the lipoid domains. We are conducting detailed studies at the present time.

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CHANGE IN CONDUCTIVITY OF ALAMETICIN-MODIFIED PHOSPHOLIPID MEMBRANES EXPOSED TO A HIGH FREQUENCY ELECTROMAGNETIC FIELD

Moscow BIOFIZIKA in Russian No 4, 1978 pp 732-733

[Article by V. V. Tyazhelov, S. I. Alekseyev, and P. A. Grigor'yev, USSR Academy of Sciences Institute of Biological Physics, Pushchino, Moscow Oblast]

[Text] Our research was conducted on lecithin membrane systems obtained with the method suggested by Mueller, et al. (1). The concentration of alameticin in the electrolyte solution was 0.8 μg/ml on both sides of the membrane. A waveguide device was assembled to irradiate the membranes with a high frequency electromagnetic field (HF EMF). Energy propagated in the waveguide as a traveling wave with a standing wave factor not greater than 1.3. The frequency of the power supply generator was 0.9 GHz. Under these experimental conditions the intensity of the internal field in the electrolyte solution is not more than $E_{max} \approx 100\sqrt{P}$ (volts/meter), where P is power supplied to the waveguide in watts. In the experiments, the duration of the irradiation pulse did not exceed 4 sec, with the intervals between pulses being not less than 10 sec. These irradiation conditions precluded heating of the electrolyte solution within the temperature measurement precision limits ($\pm$ 0.5 degrees).

When alameticin-modified bimolecular phospholipid membranes (BPM) are irradiated by an HF field, the electric vector of which is perpendicular to the plane of the membrane, we observe a reversible decline in conductivity of the BPM (by one order of magnitude and more)--see Figure 1. In the case where the electric vector of the EMF is parallel to the plane of the membrane, for practical purposes the effect does not develop for 2-3 sec. Exposure of BPM to an HF EMF in the absence of alameticin did not lead to noticeable change in membrane conductivity either.

As the salt concentration and the intensity of the EMF grow, relative change in membrane conductivity (σ_{HF}/σ) declines, with the change in σ_{HF}/σ being greater with KCl solution than with

NaCl solution (Figure 2). The reciprocals of σ_{HF}/σ are shown in the figure. However, σ_{HF}/σ does not depend on alameticin concentration.

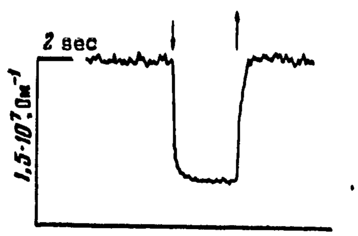

Figure 1. Change in Conductivity of Alameticin-Modified Phospholipid Membranes Irradiated by an 8w HF EMF Pulse in a 1 M KCl Solution: Arrows indicate moments when field is turned on (↓) and off (↑).

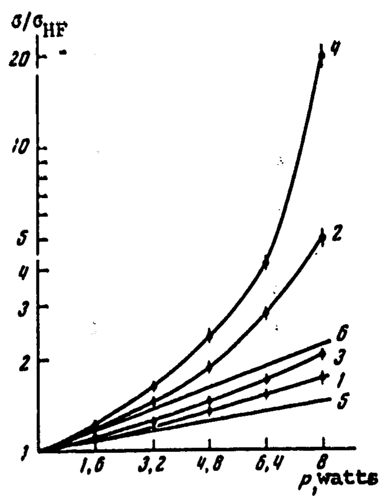

Figure 2. Dependence of Change in Membrane Conductivity on HF EMF Intensity at Different Salt Concentrations: Curves *1* and *2* correspond to 0.5 and 2 M NaCl solution; curves *3* and *4* correspond to 0.5 and 2 M KCl solution. Curves *5* and *6* illustrate the dependence $\ln(\sigma/\sigma_{HF}) \sim P_{HF}$.

It should be noted that heating can also cause a decline in conductivity of an alameticin-modified membrane, and that this change in conductivity is proportional to the increase in temperature.

Consequently change in the conductivity of an alameticin-modified membrane exposed to a field can be the product of heating of alameticin channels. In this case the decline in the system's conductivity is equivalent to heating of the channels by 12° at maximum field intensity. Because the solution is not heated during the time of irradiation, local caloric heating of membrane channels must be hypothesized.

If we assume that the observed effect has a local caloric nature, we must reject the classical values of the thermal conductivity factor for microregions such as channels in phospholipid membranes. The typical time of establishment of new conductivity values after the field is turned on (0.2-0.4 sec) and the computed magnitude of channel heating quantitatively presuppose that a channel experiences heat loss only through radiation.

In conclusion the authors express their deep gratefulness to G. N. Berestovskiy for his constant attention to the work and his discussion of its results.

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TEMPERATURE REACTION AND SURVIVAL OF EXPERIMENTAL ANIMALS EXPOSED TO VARIOUS INTENSITIES OF MICROWAVES

Moscow BYULLETEN' EKSPERIMENTAL'NOY BIOLOGII I MEDITSINY in Russian No 9, 1978 pp 282-285

[Article by V. L. Matrenina, V. M. Posadskaya and I. A. Rudakov, Scientific Research Institute of Medical Radiology (director: Prof Ye. A. Zherbin), USSR Academy of Medical Sciences, Obninsk, submitted 5 Dec 77 (presented by P. D. Gorizontov, Academician of the USSR Academy of Medical Sciences)]

[Text] A study was made of dynamics of body temperature in the course of the day, effects on this parameter in CBA mice and Wistar rats kept in containers for irradiation, as well as the temperature reaction and survival after exposure to SHF [superhigh frequency] fields varying in intensity. It was demonstrated that the extent of temperature elevation and survival rate depend on the flux density and duration of exposure. The extent of temperature elevation during exposure and extent of decline of this parameter after exposure may be considered prognostic signs of lesion due to the SHF field (BYULL. EKSPER., No 9, 1978, p 282).

Key words: SHF field; body temperature; survival rate.

It is necessary to study survival rate and temperature reactions of animals, not only when they are exposed to high intensity SHF fields [1, 3, 5, 6], but in developing methods of treatment and prevention of acute radiowave lesions [2, 4]. However, the contradictory evaluation of these parameters is attributable to the lack of a standard methodological approach. For example, some authors believe that in the case of acute radiowave lesion, the animals die primarily during exposure, while those that survive the acute factor do not die thereafter [3]. According to the observations of other researchers, the deaths occuring at the long postradiation term are of substantial significance [2]. Studies of body temperature are usually limited to the period of exposure, and they are not pursued in subsequent hours or days, although thermometric data are of considerable interest to complex evaluation of the condition of the organism following exposure to microwaves.

For this reason, our objective was to investigate the temperature reaction and survival of experimental animals of different species following exposure to thermal intensities of SHF fields.

Methods

We conducted this study on puberal DBA mice and Wistar rats. The temperature indices and survival rate were studied for 30 days after single exposure to microwaves (delivered by the physiotherapeutic Luch-58 unit in the range of the shaped wave, 2375 MHz frequency, power flux density (PPM) 10, 40 and 60 MW/cm^2, exposure time 10, 30, 45 and 60 min, ambient temperature 18-22°C, relative humidity 60-75%). The animals were irradiated in special containers made of radiolucent material and each animal was in an individual cubicle during exposure. Rectal temperature was measured using a TPEM-1 electric thermometer with a skin sensor, before exposure and at different intervals after it.

The results were submitted to processing using the criterion of Student, as well as elements of correlation and regression analysis.

Results

In the course of the day (between 0900 and 1600 hours), the body temperature of the mice drops by an average of 1.5°, and significant individual fluctuations are observed. Unlike mice, the average temperatures of rats constituted 36, 36.1 and 36.1°C at 0900, 1300 and 1600 hours, respectively.

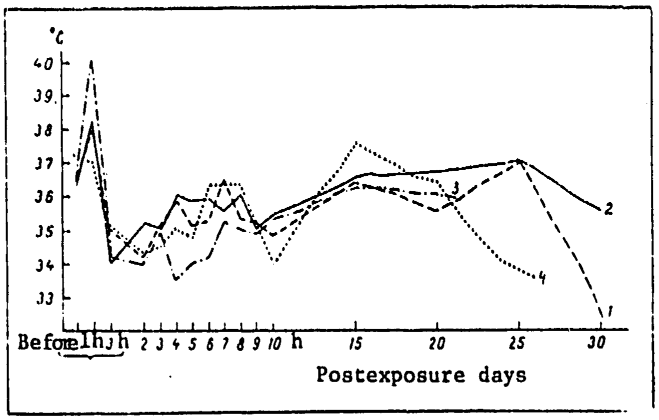
Table 1. Mean body temperature increment as function of exposure and intensity of irradiation of animals of different species

Species	PPM, MW/cm^2	Exposure time, min	ΔT, °C
Mice	40	10	0,1
	40	30	1,0
	40	45	0,9
	60	30	0,8
	60	45	1,7
Rats	10	10	0,3
	40	10	1,3
	40	30	2,1
	40	60	3,0
	60	30	2,8
	60	45	3,0

In rats exposed for 30 min (PPM = 40 MW/cm^2), motor restlessness was observed by the 10th-20th min of exposure, the animals then became listless, developing hyperemia of the ears, tail, tips of the paws and sanious discharge from the nose. The body temperature was elevated by a mean of 2.1°C immediately after exposure; 3 h later and for the next 3-5 days it remained 0.5-1.3°C lower than the initial level. Some deaths were observed on the 19th and 23d postexposure days.

In another series of tests using the same intensity of microwaves we prolonged exposure time to double the previous duration (60 min). The animals in this series could be divided into three groups: 1) those that died "under the beam" [during exposure], 2) those that died within the first 24 h after exposure and 3) those that survived or died at the long postexposure time. The initial temperature level did not affect the survival rate; at the same time, the temperature increment during exposure constituted a mean of 4°C among animals that died within the 1st day, and -1.5° among those that survived or died at the long term. The body temperature of irradiated rats dropped to 34-35°C 3 h after exposure and to 31°C in those that died within the first 24 h.

The Figure illustrates the results of thermometry on rats over a 30-day period. The body temperature of these animals remained low for the first 10 days after exposure, then reverted to normal, but dropped again prior to death on the 25th and 30th days (rats Nos 2 and 8).



Body temperature of rats following single exposure to microwaves (PPM = 40 mW/cm^2, exposure time 60 min). X-axis, time after exposure; y-axis, body temperature

1) rat No 2 2) No 4 3) No [not given] 4) No 8

A comparison of temperature increment in the course of irradiation (+Δ1) and decline thereof thereafter, in relation to the base level (-Δ1) in some animals revealed that there is a rather marked correlation between them (coefficient of correlation r = 0.66, m = -.12). Thus, a more marked temperature elevation during exposure and faster decline after exposure were observed in animals that died within 24 h after irradiation.

In analogous studies of mice exposed for 30 min with PPM = 40 MW/cm^2, there was negligible elevation of body temperature; but 3 h after exposure the rectal temperature dropped to 35.4±0.8°C in mice that subsequently survived and to 29.2±1.1°C in those that expired.

Exposure of mice and rats to 10 MW/cm^2 for different periods of time was not associated with changes in temperature or animal deaths.

Rats were found to be more sensitive to microwaves with the SHF field level and exposure method we used. As a result of exposure to SHF, the changes in temperature of mice (Table 1) and death rate thereof (Table 2) were less marked than in rats.

Table 2. Distribution of animal deaths at different postradiation times with different exposure times and intensity of radiation

Species	Number of anim.	PPM, MW/cm^2	Exposure time, min	Time of death, postrad. days								Deaths	Surviv.	Survival rate, %
				0	1	2	19	21	23	25	30			
CBA mice	8	H/O	H/O	—	—	—	—	—	—	—	—	—	8	100
	8	10	10	—	—	—	—	—	—	—	—	—	8	100
	8	40	10	—	—	—	—	—	—	—	—	—	8	100
	24	40	30	2	3	2	1	—	—	—	—	8	16	66,7
Wistar rats	8	H/O	H/O	—	—	—	—	—	—	—	—	—	8	100
	8	40	30	—	—	—	1	—	1	—	—	2	6	75
	10	40	60	4	2	—	—	1	—	1	1	9	1	10

Note: H/O--not irradiated; 0--death during exposure period.

At the present time, it is difficult to determine the causes of animal death at the long postradiation term; perhaps it is attributable to the de-adaptional influence of microwaves, lowered resistance to infections and other deleterious factors. The decline of body temperature, which we recorded for a long time after exposure, evidently related to involvement of the nervous system and impaired thermoregulation in the irradiated organism, is an indirect confirmation of the presence of persistent disturbances. The extent of elevation of body temperature during irradiation and of decline thereof after exposure may be interpreted as significant prognostic signs in the presence of acute radiowave lesion. Animal death at the long post-radiation term requires further complex investigation of the condition of the organism using methods that permit evaluation of extent of rehabilitation after exposure.

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INTERACTION BETWEEN THE BODY AND ELECTROMAGNETIC FIELDS AS AN ENVIRONMENTAL FACTOR

Kiev VZAIMODEYSTVIYE ORGANIZMA S ELEKTROMAGNITNYMY POLYAMI KAK S FAKTOROM OKRUZHAYUSHCHEY SREDY (Interaction Between the Body and Electromagnetic Fields as an Environmental Factor) in Russian 1977 signed to press 9 Dec 77, pp 2, 3-4, 227

[Annotation, foreword and table of contents from book by Andrey Mikhaylovich Serdyuk, Izdatel'stvo Naukova Dumka, 1200 copies, 228 pages]

[Text] This book deals with the question of interaction between the body and electromagnetic fields as an environmental factor. It formulates the approaches for complex evaluation of the biological effects of electromagnetic fields on organisms on different levels of organization, ranging from unicellular ones to man; it describes the methods for improving the environment in areas where there are sources of electromagnetic fields, and it sheds light on questions of continued development of the problem.

In addition to biomedical issues, the monograph deals with sociohygienic, engineering, urba-construction and other questions. It will be quite useful to scientific and practical workers in the medical and biological fields, urban builders, as well as a wide range of specialists concerned with environmental protection.

There are 37 illustrations and 44 tables; the bibliography is on pages 207-226.

Foreword

Unprecedented flowering of science, transformation thereof into a direct productive force aiding in finding the optimum solutions to social problems constitute the decisive feature of the socialistic lifestyle. Problems of increasing the effectiveness of science and making maximum use of its advances in our national economy become a powerful factor in accelerating scientific and technological progress which acquires a human direction under conditions of well-developed socialism.

Man's power over the forces of nature is constantly increasing. The past few years have shown conclusively that industrialization and scientific-technological progress are leading to an appreciable change in the environment. Man is creating, more and more intensively, an artificial habitat that makes it possible to improve living and working conditions. But, not infrequently, development of the artificial environment is in contradiction to the biological and mental distinctions of the body, which developed in the course of thousands of years of evolution. The lack of appropriate control of this process could have adverse ecological and genetic consequences, and it could be seriously detrimental to life. For this reason, it is important to define the nature of deleteriousness of environmental factors. It is impossible to provide an unequivocal evaluation thereof, due to the complexity of interaction between adverse factors and human health, as well as the shortage of data about many active factors.

At the present time, physical factors, i.e., electrical and electromagnetic, are acquiring particular significance among numerous environmental factors, including those that accompanied the evolution of living nature.

Energy capabilities are increasing in all countries of the world with each year. Continued expansion of the use, in the national economy, of various forms of energy, created or intensified by man, is unquestionable. There are the most diverse sources of generation of energy: high-frequency, for communication and radio broadcasting; microwave for radar, television and industry; infrared, for heating instruments; energy of visible light--lasers; ultraviolet radiation--bactericidal lamps; ionizing radiation for the equipment of x-ray laboratories, nuclear weapons, atomic energy installations, artificial radioactive isotopes, etc. The problem of providing for normal function of the biosphere and biogeocenoses with the ever increasing supply of energy in society consists of defining and creating conditions, under which development of industry and wide use of energy, including its new forms, would not constitute a potential hazard to man, animal and plant kingdom of our planet.

The number of works published on the biological effects of electromagnetic fields and mechanisms of their action on the organism is growing constantly. Questions of limiting the adverse effects of electromagnetic fields are discussed by many scientists in the world. These debates are based on the advances of Soviet scientists, specialists in GDR, Polish People's Republic, CSSR, the United States and other countries. At the present time, more than 700 scientists in different specialties are working on this problem. And while the problem has still not been exhaustively formulated and there are not enough data to answer the fundamental questions, every new discovery made by Soviet and foreign researchers will aid in finding the routes for continued development thereof.

This book describes distinctly the present status of the problem. There are debatable sections in it and, of course, some omissions have been made. The author devoted considerable attention to the biological role of electromagnetic fields in the radiofrequency range, as being one of the present widespread sources of energy in the environment; he has singled out unresolved or debatable aspects and defined the possible directions of future scientific research. At the present time, this problem concerns scientists in many specialties, practising physicians, engineerings, urban builders and specialists dealing with problems of environmental protection.

The author's conception of biological significance of electromagnetic fields will undoubtedly interest the reader very much and draw the attention of specialists, who will find in this monograph coverage of theoretical issues and various practical aspects.

Contents

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REACTIONS OF BIOLOGICAL SYSTEMS TO MAGNETIC FIELDS

Moscow REAKTSII BIOLOGICHESKIKH SISTEM NA MAGNITNYYE POLYA in Russian 1978 signed to press 24 Feb 78 pp 2, 213

[Annotation and Table of Contents of book edited by Yu. A. Kholodov, Izdatel'stvo Nauka, 2,250 copies, 213 pages]

[Text] The collection summarizes the achievements in the field of magnetobiology, which studies the effect of artificial and natural magnetic fields on biological systems. The reactions of various levels of organization of biological systems, from molecular to population, are described. Notice is taken of the relationship of biological reactions to the parameters of the magnetic field in effect, which to a certain extent makes it possible to control the activity of the bio-object, by changing the parameters of the field. The bionic, ecological, therapeutic and hygienic aspects of magnetobiology are discussed.

The book is designed for a broad range of readers: biologists, medical personnel in various specialties, physicists, engineers and technicians interested in biological problems.

Table of Contents

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